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Soil Moisture and Environmental Temperature and Humidity Sensor-Based Data Breaches in IoT Enable Irrigation System Design using Arduino and FPGA

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Abstract

In this work, we have successfully implemented a Moisturization sensor to detect the presence of moisture and trigger pump to on/off depending on the presence of moisture in the soil. The implementation of soil moisture sensor is done on the Arduino board using Yl-69 sensor and the implementation of temperature and humidity is done on Field Programmable Gate Array (FPGA) device. Artix-7 FPGA is used for interfacing the sensor. FPGA devices not only display the temperature value but also makes the whole system power-efficient. We have also surveyed the required water content in soil for the ideal production of crops. We set a threshold level of moisture for every crop if moisture will be less than threshold then pump will automatically start otherwise pump will stop. We have also observed that Sugarcane consumes the maximum amount of water among the list of surveyed crops in Table 1. The minimum amount of water is required by Bean. Therefore, pump up time will greater for sugarcane and minimum for bean

Keywords: Moisture, Humidity, Sensor, Pump, FPGA, Arduino, Smart Irrigation System

1. Introduction

In this work, we are using three electronics equipment: Sensor, Pump, and Controller as shown in Fig. 1. There are two varieties of controller: FPGA and Arduino.

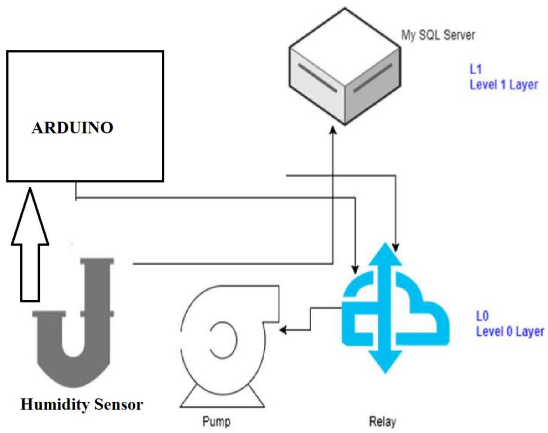


Fig.1 Schematics of Smart Irrigation System

The soil moisture **sensor** or the hygrometer is basically used to check the presence of the water content in the soil. So, it is an ideal component to build a smart irrigation system to control soil moisture for the healthy development of crops and plants. The **Soil Moisture Sensor** takes capacitance to measure the dielectric permittivity of the Soil. In **soil**, dielectric permittivity is proportional to the moisture. The **sensor** generates a voltage corresponding to the dielectric permittivity as shown in Fig. 2, and therefore the moisture of the **soil** quantified.

Fig.2 Relation between Water Content and Output Voltage

The pump provides one liter of water per minute in ON state. The pump provides zero liters of water per minute in OFF state [1]. The pump (as shown in Fig. 3) used in our smart irrigation system needs voltage in a range of 165–250 V and required power is in the range of 12-40 W. A mounting form of relay is used for power supply. We have connected one relay to pump as shown in Fig. 3 [1].

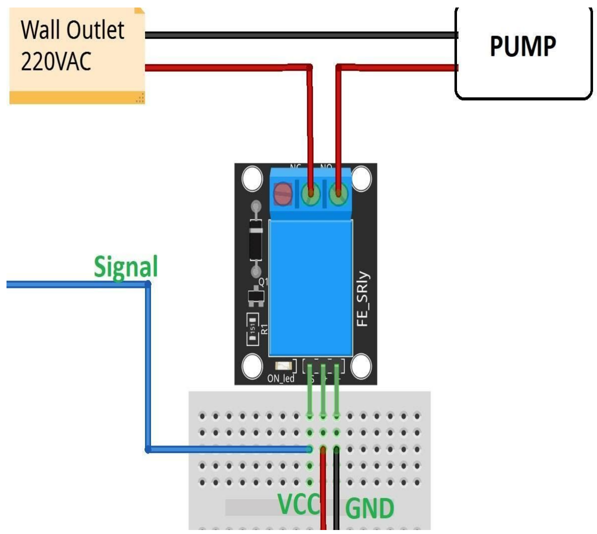


Fig.3 PUMP Connected with Relay, Signal and Power Supply [17]

2. Related Works

This section explores the various work conducted by the researchers in the field of modern agriculture techniques. In [2] resistivity of a homogeneous soil is computed as R_s=12.6*a*R where R is soil resistance (can be measured by YL-69 sensor) A is spacing between the electrodes that is 1.3 cm in case of YL-69.In [3] DHT and YL-69 modules are used to monitor soil characteristics, moisture, weather conditions, and temperature data which is then sent to the webpage through the Wi-Fi module and a message alert are also sent via GSM module attached to device. In [4] paper discusses the use of a YL-69 sensor to display moisture value on LCD. The system is also connected to a relay to turn on the pump if the moisture level is below 15%. In[9] a review of different soil sensing techniques, laboratory analysis of soil, application of artificial fertilizers is given. In [5] sensors and actuators are controlled by Raspberry Pi which is running a nodejs application. In [6] the importance of calibration process to obtain reliable data in case of soil moisture sensor is stated we can calibrate our sensor using the potentiometer present on the module. In [7] authors have provided approximate water requirement data for different crops as shown in Table 1. In [10] a real-time system based on FPGA is executed to record relative humidity and drying soil curve. It is a data logger device to log and analyze the data in future to make suitable changes in agriculture methods. In [11] we get to know the basics of Arduino Uno, it's a working and efficient coding scheme. In [12] we come to know about the libraries present in the Arduino IDE and their usage in real-time application development. In [13] a temperature sensor LM32 is connected to Arduino. A complete simulation, as well as hardware implementation, is also given. In [14] again LM32 is used but in this case a smart ventilation fan is used to keep the system in desired temperature. In [15] Arduino based basic electronics components tester is built. In [16] data logger is built using Arduino and Android devices in Real-time. In [16] the presence of CO2 and CO gas is detected and GSM module is interfaced with Arduino to send SMS to desired mobile phones. MQ2 and MQ4 sensors are used in detection of CO2 and CO respectively.

Table 1: Water needed by different crops.

Crop	Crop water need (mm/total growing period)
Alfalfa	800-1600
Banana	1200-2200
Barley/Oats/Wheat	450-650
Bean	300-500
Cabbage	350-500
Citrus	900-1200
Cotton	700-1300
Maize	500-800
Melon	400-600
Onion	350-550
Peanut	500-700
Pea	350-500
Pepper	600-900
Potato	500-700
Rice (paddy)	450-700
Sorghum/Millet	450-650
Soybean	450-700
Sugarbeet	550-750
Sugarcane	1500-2500
Sunflower	600-1000
Tomato	400-800

3. Experimental Setup

Fig 4. is the experimental setup for the reading moisture content of the soil.

- Experiments have found that the yl-69 sensor value is around 650 when there is no moisture present in soil or the sensor is placed in air, therefore, it is the maximum resistance value given by the sensor. Similarly when we place the sensor in moist soil the sensor value is around 250-280.
- Also, when we short circuit the electrodes of the sensor we get the sensor reading 0 as output.
- If we relate the data from Table 1 and data from our observations we find that as the Crop water requirement is high the cutoff limit on the pump decreases. Hence, an approximate cutoff limit set in the program using inversely proportional relation between limit and required water value is shown in Fig. 5.
- From Table 1 we can conclude that Sugarcane consumes the maximum amount of water among the list so proportionate its value 2500(highest limit) to 100 in our Arduino code.
- The minimum amount of water is required by Bean so proportionate its value 500(highest limit) to 650
- And to find the actual limit of the program we have taken average values of water needed by crop and proportionate them to values accordingly as shown in Fig.5.

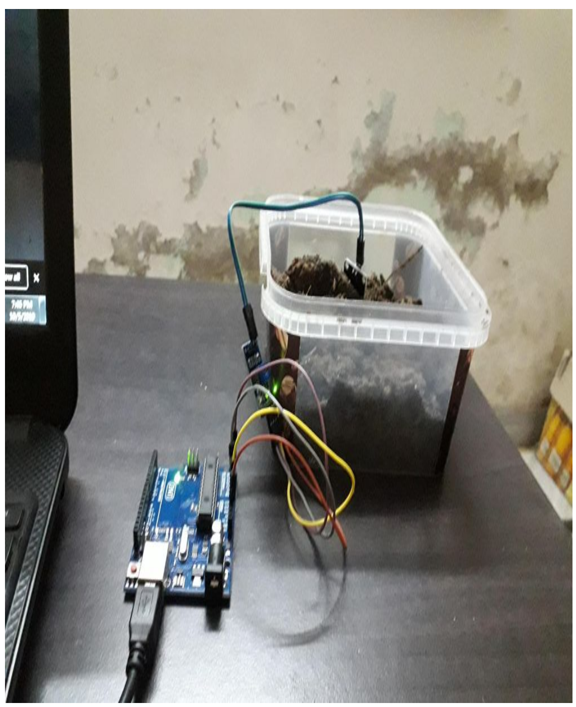


Fig. 4: Experimental Setup

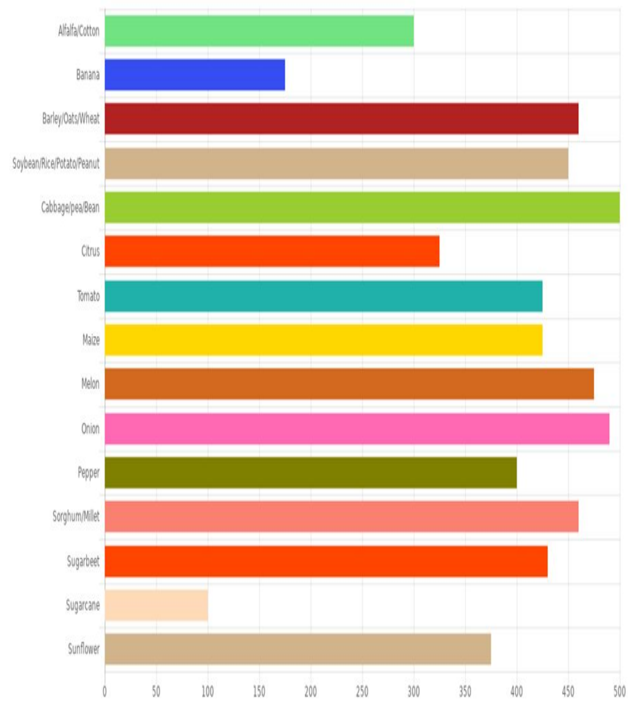


Fig. 5: Proportionate limits executed in the Arduino program.

Y-axes of graphs shows the different crop names and X-axes is their limit in the Arduino program. As we can see Sugarcane and Banana have the minimum limit value which is the maximum conductivity between the electrodes of the sensors.

4. FPGA Implementation of Soil Humidity and Temperature Sensor

The FPGA implementation of soil humidity and the temperature is done on Vivado Design Suite and the results are observed on Artix-7 FPGA with the help of **sht-10** sensor. The sht-10 sensor measures the temperature and humidity of the soil's environment. The code of the sht-10 sensor is written in Verilog Hardware Description Language (HDL). For the implementation of sht-10 sensor on Artix-7 FPGA the number of Flip-Flops (FF) used are 131, the number of Look-Up Tables (LUTs) used are 792, the number of Input/Output (I/O) used are 19, the number of Digital Signal Processing (DSP) slices are 2, and the number of Global Buffer (BUFGs) used is 1. The resources utilized in the FPGA implementation of the sht-10 sensor are shown in table [2].

Table [2]. Resource utilization of FPGA.

Resources	Utilization	Available
FF	131	126800
LUTs	792	63400

I/O	19	210
DSP	2	240
BUFGs	1	32

This temperature and humidity sensor also promotes the ideas of green communication by consuming the very least amount of power. The total power consumption of FPGA is 0.129W, which is the combination of device static power and dynamic power. The static power consumption is 0.097W which is 75% of the total power and the dynamic power consumption is 0.032W which is 25% of the total power. The static power of the device is the combination of clock power which is 0.003W, signals power which is 0.007W, logic power which is 0.006W, DSP power which is 0.002W and the I/O power which is 0.015W. The power consumption of Artix-7 FPGA is shown in fig 6.

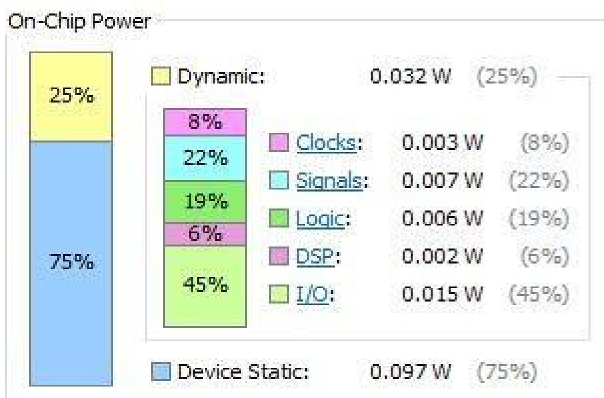


Fig. [6] Power consumption of Artix-7 FPGA.

The results of temperature and humidity are observed on the Artix-7 FPGA board which is shown in fig 7.

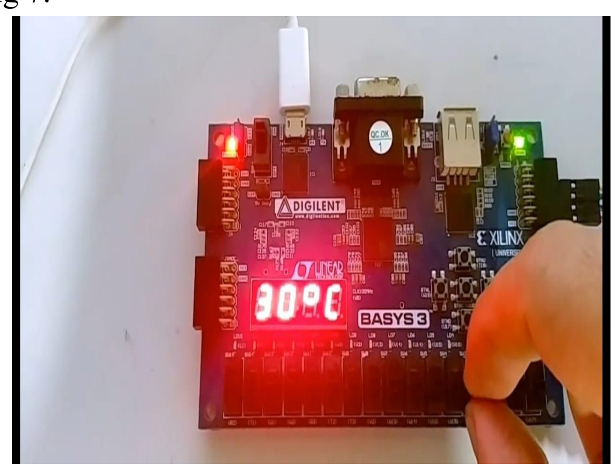


Fig. [7] Temperature on FPGA board

6. Results and Analysis

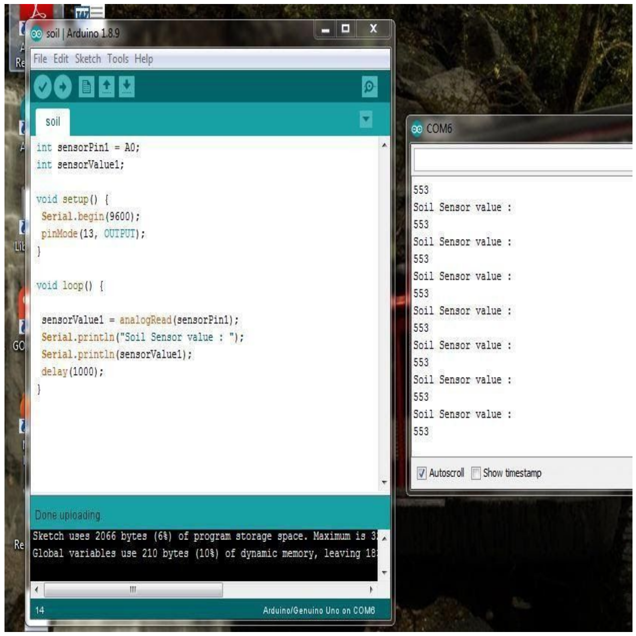
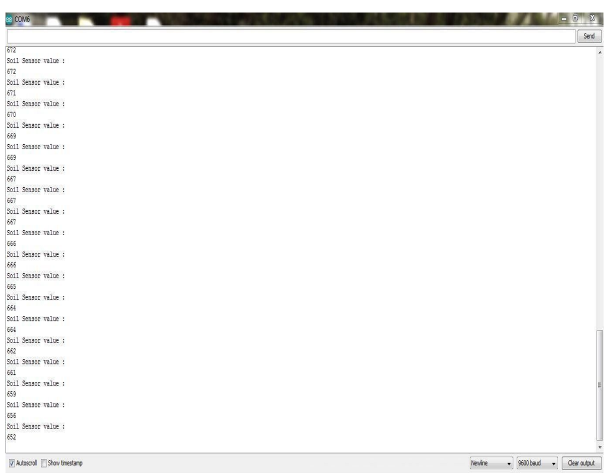


Fig. [8]: Soil sensor value in dry soil.

YL -69 sensor has two parts sensor electrodes and comparator modules. The electronic sensor has two outputs connected to the comparator module which has two output pin one with digital output and other with analog output. The threshold of the digital output can be set by an on-board potentiometer according to the soil moisture requirement.



Fig[9]: Soil Sensor value in air.

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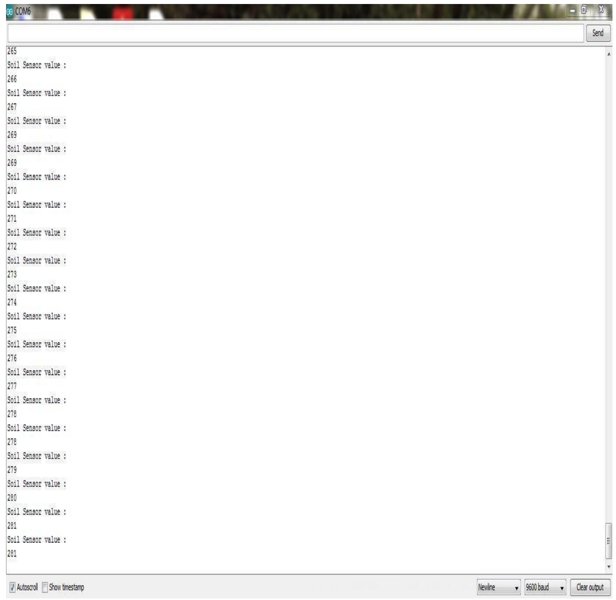

Fig[10]: Soil Sensor value after pouring water in the soil.

Fig. 9 and Fig. 10 gives us the Real-time data of the physical resistance value between the electrodes at two extremes environmental settings. Fig. 9 gives us the value of the resistance in air and Fig. 10 gives us the value of soil resistance when moisture is added to the soil.

7. Conclusion

The project is providing new data for Arduino execution of the soil moisture sensor. Arduino is a good open-source prototyping board to implement comparator extended sensors like YL-69. The output readings of the sensor can be easily manipulated according to our environmental needs but if we want to change some data or set new limits in the field we have to use FPGA. The same limits as proposed by the authors in Arduino can be used in interfacing Yl-69 sensors with FPGA. Not only this, with the help of the Sht-10 sensor the temperature and the humidity of the environment is also measured. The FPGA device also makes the whole experiment suitable for promoting the ideas of green communication by consuming very least amount of power which is 0.129W.

8. Future Work

The soil moisture, temperature, and humidity are the mechanical and physical attributes of sensing in future the chemical composition of the soil should be analyzed using infrared sensing, spectra analysis, x-ray fluorescence techniques such techniques are used in laboratories but the Real-time execution of these is needed. To upgrade the irrigation methods drones can be used to sprinkle water and fertilizers in fields that can also be used to detect the plant diseases using image processing and artificial intelligence. Further work can be done on different farming practices like cattle management, crop rotation, etc.

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